No. 8

Western Region Technical Memorandum

# INTERPRETING THE RAREP

by

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ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION
U. S. WEATHER BUREAU

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## I - INTRODUCTION

The maximum utilization of radar intelligence is dependent on several factors. Two of the most important are: (1) the ability to communicate a three-dimensional description of the radar returns; (2) the ability of the "user" to interpret these reports in terms of meteorological significance, based on a thorough understanding of the radar's capability and limitations.

A great deal of study has been given to the problem of radar data communication. The problems are many, and we recognize that a few of the procedures currently in use fall short of conveying desired radar intelligence. However, new techniques and communications systems are currently in the development stage which will add materially to our capability to communicate radar data. In the interim, it behooves us to gain a better understanding of reporting procedures and how to interpret the radar report to achieve maximum information.

In this discussion, the techniques involved in the preparation of the SD or RAREP code will be described along with how they should be interpreted in light of the capability and limitation of the WSR-57 radar system. A complete detailed description of radar-reporting procedures is contained in the Weather Radar Surveillance Manual.1/

## II - THE RAREP CODE

All WSR-57 radar stations, whether reporting on RAWARC* or directly on the Service A teleprinter circuit, are required to report radar data in coded form in accordance with instructions contained in the Weather Radar Surveillance Manual.[1] It is important for the user to be able to interpret these messages and to know the format of the message since some of the data are identified only by their position in the message. It should be helpful, therefore, if we take each element of the radar report (RAREP) and discuss it in order of its occurrence. Figure (1) is a condensed explanation of the RAREP code. In the Western Region, AZRAN points have been replaced by geographical locations in the RAREP.

* Internal Weather Bureau RAREP and Warning Coordination System

a. Time of Observation

Because of the nonexistence of a RAWARC circuit at most of our stations in the Far West, radar stations must file their radar reports directly on Service A. Regularly scheduled radar reports (SD's) are filed at the H+20 scan period. When circuit time permits, specials are filed at H+40. Radar reports are made only when echoes are actually observed on the scope; otherwise, radar status reports are filed at three-hourly intervals at synoptic times. The time ascribed to the SD report is the time the last entry is made. The radar meteorologist plans his observation in light of its complexity to ensure delivery to the communicator by no later than H+15 minutes. The radar report can take as long as 15 minutes to prepare. Normally, the report is prepared as close to the hour as possible so as to be comparable with visual airway or synoptic observations. The user must be cognizant of the fact that since this observation is not filed until H+20, the report may be as much as 30 minutes old before he receives it.

It should be emphasized at this point that while it is important to know the exact time of the observation, the time delay due to communication is not a critical factor in most instances. The exception, of course, would be when reporting severe weather. In this case, other means of communication are utilized. The user should remember that the RAREP represents an instaneous depiction of the mesoscale precipitation pattern with elements in all stages of development. Because of the constantly moving elements and their highly perishable nature, one could not be sure of their location or existence even a few minutes after observation time. The maximized use of radar intelligence does not lie in its capability to pinpoint weather elements, but rather in its use in combination with other information to increase our knowledge of the current synoptic situation and hopefully provide better prognoses, at least on a short-term basis.

b. Character of Echoes

The character of the precipitation echoes in the RAREP is described as: CELL, AREA, LINE OR LAYER followed by a symbol indicating the coverage by echoes in the area or line designated. The symbol for the amount of coverage is used in the same manner as the sky symbols used in aviation weather reports; i.e., ⦶ = 1/10 to 5/10, ⦷ = 6/10 to 9/10, ⊕ = 10/10. An exception is the use of the word WIDELY to indicate less than 1/10 coverage. (see Fig. 1)

Before proper interpretation of these data can be made, the user must have an understanding of what the radar is capable of detecting. The WSR-57 radar system has been designed to operate on a 10cm wavelength. Normally 10cm radar will not receive back scatter from cloud droplets. Therefore, echoes detected and reported in the RAREP are actually raindrops or ice particles. An exception to this may occur with very wet clouds at close range.

The user should be aware that an area or line reported as scattered or broken may be, and most probably is, associated with extensive cloud systems. This fact becomes very important when briefing pilots from radar data. The user cannot imply that VFR conditions exist between echoes in areas reported as scattered or broken.

Another factor which must be considered when making interpretations of the character of the echo is the propagation of the radar beam. Figure 2 shows a typical radar-beam pattern. Radar propagation is essentially line-of-sight curving slightly due to atmospheric refraction. Assuming standard atmospheric refraction, the beam bends with a radius of curvature of 1.33 times that of the earth's radius. It can be seen that the radar beam has an apparent rise above the earth's surface with range. Therefore, the greater the distance from the radar site, the higher above ground will be the radar sampling volume. The precipitation detected at these elevated levels may not be representative of precipitation at ground level. In fact, the precipitation may not be reaching the ground at all. Precipitation aloft detected in this manner is reported in the RAREP as a "LAYER" with the top and base included.[1/]

The apparent rise in elevation of the radar beam with range also results, quite often, in reporting "Coverage" (⌀ or ⦶) somewhat less than that which actually exists. A solid rainshield at ranges beyond 100 miles may appear on the radar scope as broken or scattered. This is because the radar beam is passing above most of the precipitation with only the higher cells reaching up into the radar beam. This situation sometimes occurs with cold winter-type storms whose tops reach to only 16,000 to 20,000 feet. The term applied to this situation is called "overshooting".

Overshooting is particularly troublesome when attempting to forecast the cessation of precipitation. It cannot be determined in all cases that the back side of the precipitation shield is being seen by radar. It may only appear to be seen, due to overshooting of the radar beam. Oftentimes the experienced radar meteorologist can determine whether the radar beam is overshooting or actually detecting the back side of the storm, in which case he will usually add remarks to this effect in the RAREP. The user should avoid drawing conclusions regarding the areal extent of large precipitation patterns based on data derived from the SD report unless remarks to these effects have been included.

c. Type of Precipitation

The distinction between showery and continuous-type precipitation is easily made by the radar with a high degree of accuracy. Each type has very definite characteristics when viewed on the PPI* or RHI** scopes. These are reported in the RAREP as R or RW in the case of rain and rain showers and S or SW for snow.

d. Thunderstorms

The determination of the occurrence of a thunderstorm cannot be made with absolute certainty from radar returns alone. The ionized path of lightning discharges has been detected by various radars, including the WSR-57; but these have been very rare events requiring constant vigilance and considerable luck. However, through careful analysis of individual echoes with regard to their intensity and height, statistical probabilities can be applied. For example, a study conducted at Missoula, Montana[2] showed that about 80 percent of the echoes observed between 40 and 200 nm of the station in the moderate and strong category were associated with thunderstorms. In the Midwest[3] studies showed that about 80 percent of echoes in the strong category and about 50 percent in the moderate category were thunderstorms. Of the echoes indicating a radar height of 40,000 feet, 85 percent were thunderstorms; and of the echoes with heights between 30,000 and 40,000 feet about 60 percent were thunderstorms. When reporting a thunderstorm based on these types of data, the radar meteorologist will generally include in the remarks portion of the RAREP, "PRBL TRW". Fortunately, the radar meteorologist has other information available to him such as aviation surface reports, pilot reports, and various other reporting networks such as the Forest Service or State Forest Agencies from which he can glean reports of thunderstorms or hail which he can relate to the radar returns.

* PPI - Plan Position Indicator
** RHI - Range-Height Indicator

## e. Hail

It is not possible to distinguish hail using radar returns alone. However, researchers have established an empirical relationship between the occurrence of hail and storm reflectivity in the strong category[4]. The user should be alert to the possibility of hail in association with echoes reported as TRW+. The radar meteorologist will append a suitable remark to the RAREP if hail is known to exist with certain echoes.

## f. Intensity

The intensity assigned to a radar echo is determined by the radar meteorologist employing an objective method based on an empirical relationship between radar reflectivity and rain intensity. In order that the user may make most effective use of these data it is necessary to have some idea of the physical principles involved. Basically, the radar transmits a very short burst of energy, then listens for that small portion of the energy back-scattered from the target. The power received from the target is a function of the radar design parameters and the reflective qualities of the target. In the case of precipitation targets, it has been shown theoretically that the power which is back-scattered to the radar antenna is proportional to the summation of the sixth power of the drop diameter.[5] This is expressed mathmatically in the form: $Z = D^6$, where Z is radar reflectivity $mm^6m^{-3}$.* The average power received by a radar system from a precipitation target is given by the following equation:

$$\bar{P}_r = \frac{P_t C Z}{r^2} \qquad (1)$$

This equation states that the average power received ($\bar{P}_r$) is directly proportional to the power transmitted ($P_t$), the radar constant (C) and the precipitation reflectivity (Z) and is inversely proportional to the square of the range (r). Included in the radar constant (C) are the radar design parameters such as antenna gain, vertical and horizontal beam width, pulse length, wavelength and a term for the complex index of refraction.

Solving for radar reflectivity, equation (1) becomes:

* mm - millimeter
m - meter

$$Z = \frac{\overline{P}_r \; r^2}{P_t \; C} \qquad (2)$$

The final step is to relate the radar reflectivity derived from equation (2) to rainfall rate (R). Over the past 15 years, numerous studies have been conducted to establish the relationship of Z to R.[5] Many factors are known to affect the Z-R relationship, such as drop size and type of precipitation. For example, a few large drops can produce reflectivity values as great or greater than many small droplets.

Equation (3) proposed by Marshall and Palmer is considered to be representative for most rains and is used by the U.S. Weather Bureau.

$$Z = 200R^{1.60} \qquad (3)$$

where Z is in $mm^6/m^3$ and R in mm/hr.

In the theoretical derivation of radar echo intensity a number of assumptions are necessary. It is not within the scope of this discussion to mention all of them, but we should point out the more important ones and how they may affect the interpretation of these data. In equation (1) the power received ($P_r$) is inversely proportional to the square of the range ($r^2$). This is an important assumption since it implies that the meteorological target completely fills the radar sampling volume. In actual practice the meteorological target does not always fill the beam, particularly at extended ranges (See Figure 3). The range attenuation factor in the radar equation for a point target would be $\frac{1}{r^4}$. Therefore, for a precipitation target, partially filling the radar beam might conceivably result in an attenuation factor of $\frac{1}{r^3}$ or some other variation of the exponent. The net result is generally an under-estimation of echo intensity at extended ranges, particularly when the echoes are of limited vertical extent. Because of this intensity error at extended ranges, radar intensity measurements are not made at ranges beyond 125 nautical miles.[1] Often the effects of overshooting or partial beam filling occur well within the 125-mile limitation; the user should be cognizant of reported storm heights and exercise his judgment accordingly. For example, winter storms approaching the West Coast of California are often quite shallow, having tops to 12,000 or 16,000 feet resulting in a radar intensity classification of weak when in fact it may be moderate. While the Z-R relationship expressed in equation (3) is probably representative of most rains, it is based on assumptions which do not always occur in nature. For example, the target is assumed to be comprised of liquid, spherical rain drops of average size and distribution[4]. Actually the sampled volume may be comprised of large flattened droplets or water-coated ice spheroids or any combination of these. The reflectivity or scattering properties vary considerably with the precipitation state. Snow reflectivity is very complex and is not clearly established. Therefore, intensities from snow echoes are not determined and are reported in the RAREP as unknown (U) regardless of range.

In spite of these problems, the radar can and does give us a reasonably good estimate of storm intensity to a range of 125 nautical miles. The present method of classifying radar intensity in five categories (very weak, weak, moderate, strong and very strong) has been fairly well correlated with weather types and precipitation intensities [2,3,5,6].

Particular emphasis has been placed on the correlation of radar storm reflectivity with the occurrence of severe weather. Radar echoes reported in the "strong" category correlate rather highly with the occurrence of thunderstorms, hail and damaging winds.

The use of the radar intensity data often leads the user to some conclusions or assumptions that are not necessarily true. We should like to call your attention to them:

1. The radar intensity classifications, while related to theoretically derived rainfall rates, do not correspond directly with precipitation intensity reported in regular surface observations. The criteria for surface observations and radar are shown below;

| Surface Observations(Cir. N) | | Radar | |
|---|---|---|---|
| R-- Very light | less than .01 in/hr | R-- Very weak | .0001 to .01 in/hr |
| R- Light | .01 to .10 in/hr | R- Weak | .01 to .10 in/hr |
| R Moderate | .10 to .30 in/hr | R Moderate | .10 to 1.00 in/hr |
| R+ Heavy | more than .30 in/hr | R+ Heavy | 1.00 to 5.00 in/hr |
| | | R++Very Heavy | more than 5.00 in/hr |

2. The probability that the radar intensity will correspond with raingage data directly under a given echo is not high. There are several reasons for this: 1. The radar beam is sampling at some distance above ground level. Due to fall velocity, coalescence, trajectory and evaporation, there can be quite a difference between the radar estimation and the precipitation caught at ground level.

2. The radar estimate is an instantaneous reading and is integrated over a large sample volume while the raingage samples about a square foot over many hours.

In summary, radar can provide an estimate of storm intensity, based on theoretical and empirical relationships, in five categories, operationally useful to the user. Recent work by researchers[6] show, that point rainfall estimates are within a factor of 2 when compared to raingage measurements. Hopefully the day will come when radar will provide precise rainfall measurements; however, at present a more realistic view is to use radar to augment raingage networks.

### g. Tendency

Tendency is reported in the RAREP in the manner shown in Figure 1. While perhaps this section of the code is self-explanatory, some clarifications are necessary. Tendency data is based on change and rate of change of the radar reflectivity. Technically it has nothing to do with the hourly increase or decrease in the number of echoes. In some instances, it becomes quite difficult for the radar meteorologist to be completely objective in the determination of tendency. These situations occur when there are a large number of reported cells. It is impossible to measure the reflectivity of each cell and compare it with the reflectivity of the previous hour. In these cases a representative sample is measured and applied to the entire area. Important cells with strong or very strong returns are usually reported separately, in which case the tendency applies to the individual cell.

The tendency data in the RAREP has proven to be most useful to the user since it reflects the dynamics of the situation. Fire-weather forecasters and fire dispatchers make particular use of these data in airmass thunderstorm conditions.

### h. Location

The location of the echoes is given several ways, depending on the type or configuration of the echoes.

1. Area — An area is bounded by the minimum number of points necessary to include the echoes and, at the same time, show in as much detail as possible the area affected. Such an area may have another area reported within it to describe important smaller features. Lines may also be reported within the boundaries of a larger area.

2. Line -- A line on the radar scope is regarded as an echo configuration which is at least five times longer than it is wide. These lines are reported by giving the end points of a line through the axis and the width of the line. When the line is curved, additional points will be given along the axis.

3. Cells -- In the case of particularly important cells, or when there are only a few on the scope, the radar meteorologist will code them separately. In this case, the location will be the center of the cell. The diameter of the cell follows the location point. For instance, D10 means diameter 10 nautical miles.

The area of echo coverage represents only that area of the storm located within the radar range of detection. Therefore, the radar sees only a portion of the synoptic scale weather pattern. Radar is a mesoscale tool and should be used in conjunction with other synoptic scale data. When used carefully, radar can provide important input to the synoptic scale analysis.

## i. Echo Movement

Determining the movement of various echo patterns or cells can be quite difficult at times. The problem is compounded by mesoscale circulations superimposed on synoptic scale circulations, as well as the effects of propagation and terrain. To illustrate, Figure 4 shows such a complex problem. Included on Figure 4 is an example of the RAREP that would accompany this situation. Note how the radar meteorologist has reported the various movements. In that portion of the report dealing with the line, the first direction and speed (3010) refer to the movement normal to the line (300 degrees at 10 kts.). In the remarks section the direction and speed of the elements or cells are reported 2415 (240 degrees at 15 knots). The movement of the line is based on successive position over a period of one to several hours, depending on the persistence of line. The movement of the elements or cells is based on a much shorter time interval since individual cells are forming and dissipating along the line and have a life expectancy of less than an hour.

In the case of the AREA, the cells are moving 2415 but the area itself is stationary. This situation occurs frequently on the windward slopes of mountains such as the Sierra Nevada. Echoes forming in the foothills move to the ridge and dissipate, having a net result of cell movement within a stationary area. This same situation also develops when the echo area is very large covering the entire area of radar detection. Cells moving into the surveillance area on one side and exiting on the other would result in a report of stationary area with cell movement.

Considerable work has been done in attempting to correlate echo movement with wind fields at various levels. A study of the movement of convective activity over Northern and Central California by Benner, et al,[7] points out the important role terrain plays in the speed and movement of cells. Cell movement in this area was found to conform rather closely with the upper-wind flow. Lines and areas generally moved in the same direction as the broad-scale features. Studies by J. Osborne, et al, of convective cells over the Northern Rockies show a high correlation (.91) between the 14,000 ft winds and convective cells, with a mean angular deviation of 3.8 degrees. Speed of movement also correlated highly with the 14,000 wind speed yielding a correlation coefficient of .75 with a mean deviation of 4.5 knots.

Certainly the effectiveness of radar as a short-term forecasting tool would be enhanced if echo movement could be predicted with 100% accuracy. Unfortunately, due to the complexity of the problem, this cannot be done. Terrain effect, life expectancy and propagation all have a profound effect. On the very short-term (less than one hour) basis, pure extrapolation based on current velocity provides the most reliable prognoses. On the longer-term basis, 2 to 3 hours, other considerations have to be taken into account such as synoptic climatology, local topography and the synoptic situation. Petersen[8] in Weather Bureau Technical Note No. 17 has compiled objective aids to predict echo movement with particular emphasis on work done by Newton and Frankhauser. Technical Note 17 is recommended reading for all users of radar data.

j. Echo Tops

The top of the precipitation column is determined by vertically scanning the precipitation area. The target is displayed on the Range-Height Indicator (RHI Scope) where the top height measurement is read off to the nearest 1000 feet. The height-finding capability is limited operationally to 100 nautical miles range. This is due mainly to the very large change in height which occurs beyond this range with very small changes in elevation angle. Therefore, height measurements are not made on echoes beyond 100 nautical mile range from the radar. It should be remembered that the radar top refers to the vertical extent of the precipitating column within the cloud. The visual cloud top can, and most often does, extend above this precipitating column. In practice the user should assume 1000 to 1500 ft. for the difference between the visual top of the cloud and the radar top.

As is the case in reporting echo intensity, echo top measurements are only a sampling. Time will not permit the measurement of every echo display on the scope. As a rule the top measurement included in the RAREP is the maximum top observed. Occasionally the radar meteorologist will report "average tops" or give a range of tops, e.g., TOPS 150-200.

k. Bright Band

Frequently the radar report will include the contraction "BRGT BAND" followed by two figures designating the elevation of this phenomenon. Bright Band data is not always included since the Bright Band is only observed during relatively stable conditions and seldom beyond 25 nautical miles from the radar site. The Bright Band is observed on the radar RHI Scope which displays the vertical profile of the target. It appears as a narrow band of intensified radar signal a short distance below the $0^{\circ}$ C isotherm. This phenomenon is caused by several factors associated with the changing of frozen precipitation to liquid water droplets. Briefly, frozen particles such as snow and small ice particles reflect 1/5 the radar energy that liquid water droplets reflect. As these particles fall through the $0^{\circ}$ C isotherm they begin to melt and become water-coated. At this stage their reflectivity is considerably higher. As they continue to fall and change to liquid spheroids, their fall velocity is increased resulting in less reflectivity immediately below the Bright Band. The net result is a narrow band of high radar reflectivity through the melting layer. Perhaps from the user's standpoint it would have been better had this phenomenon been called the "Melting Layer" rather than Bright Band.

There are several applications of Bright Band data:

1. By compensating slightly for fall velocity, a fair determination of the altitude of the $0^{\circ}$ C isotherm can be made.

2. A local study conducted by the WBO, Sacramento, California revealed a high correlation between the base of the Bright Band and the snow level in the surrounding mountains.

3. The occurrence of the Bright Band is indicative of stable conditions. This phenomenon is seldom observed during the growing process of convective storms since vertical currents cause the melting process to be mixed through too deep a layer. Sometimes the Bright Band will be observed during the dissipating stage of convective storms.

4. Bright Band data can be very useful to the hydrologist since it provides real-time information regarding the changes in the freezing level. This becomes very important in mountain water sheds where a change in the snow line can make a considerable difference in the area contributing to runoff.

l. Remarks

The remarks section of the RAREP is one of the most important parts of the message. Here the radar meteorologist includes pertinent remarks dealing with reported echoes or supplementary data gathered from other sources. The radar meteorologist is encouraged to include any or all information or interpretations he feels are pertinent. This is a particularly difficult task for the radar meteorologist since he must have the astuteness to include data that serves the needs of various meteorological and hydrological programs and still keep the message short and concise.

## III - RAREPS FROM OTHER THAN WEATHER BUREAU RADARS

Because of the lack of complete weather radar coverage, particularly in the West, we have encouraged the collection of radar information from cooperative agencies. These agencies include the Air Defense Command, Federal Aviation Agency and Universities. Radar reports from these agencies are usually collected by local Weather Bureau offices and, when appropriate, disseminated over long-line teletype networks. In the West where RAWARC is not yet available, these reports are filed on Circuit A during scan periods.

Radar reports from cooperative agencies have proven to be most useful, particularly in regions of sparse data; however, the user should be careful in interpretating these reports. For example, reports are taken by operators who for the most part are unskilled in meteorological interpretation and analysis. Further, the radar systems employed are not always designed for detecting and measuring meteorological targets. As a result the radar report usually provides little more than the fact that a meteorological target exists and some idea of its areal extent and movement.
It should be emphasized that in most cases the RAREPS from cooperative agencies are observed, coded and filed without the expertise of a qualified radar meteorologist. However, this fact should not deter us from gathering all radar information we can from cooperative agencies, since even a little information is better than none.

## IV - ARTC RADAR - SALT LAKE CITY

One exception in regard to the quality and completeness of radar reports from cooperative agency radars will be those disseminated from the Salt Lake City Air Route Traffic Control Center beginning early in the summer of 1966. The weather radar surveillance program at the ARTC Center will be conducted by a fully qualified staff of Weather Bureau Radar Meteorologists. While the FAA radars are not equal to the Weather Bureau's WSR-57 radar in regard to weather detection, their capabilities when coupled with other data such as pilot reports and expert analysis techniques employed by radar meteorologists will combine to provide radar reports of considerable value. Figure 5 shows the approximate area of radar coverage provided by radar systems monitored at the Salt Lake City ARTC. The seven radar systems afford us the opportunity to composite echo data over this vast area showing small synoptic scale systems in their entirety. (See figure 6.) Radar reports from this facility will of necessity be somewhat different than those from other radar stations. These reports will be in narrative form describing the entire composited radar returns. An example of such a report is included in Figure 7. In addition radar data will be transmitted from the ARTC Center via closed facsimile loop to the Salt Lake City Forecast Center.

## REFERENCES


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7. Summer Convective Cell Patterns over Northern and Central California -- Benner, et al, <u>Monthly Weather Review</u>, 1962 Vol. 90, p. 425-430.

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# CONDENSED EXPLANATION OF RAREP (SD) CODE

EFFECTIVE DECEMBER 1, 1962

| LOCATION IDENTIFIERS | TIME OF REPORT | * | CHARACTER OF ECHOES | WEATHER AND INTENSITY | INTENSITY TENDENCY | LOCATION AND DIMENSIONS OF ECHOES | MOVEMENT | HEIGHT | REMARKS ON UNUSUAL ECHO FORMATIONS |
|---|---|---|---|---|---|---|---|---|---|
| DCA | 1612 | SPL | AREA⦶ | TRW− | /+ − | 316/83 187/80 60W | ➤30 | TOPS 350 | 3/4 INCH HAIL 310/45 |

## DECODED REPORT
Washington National Airport. Special observation at 1612, broken area of echoes containing thunderstorms producing light rain showers at the surface. These echoes are slowly increasing in intensity. Area extends from 316° 83 nautical miles to 187° 80 nautical miles, is 60 nautical miles wide, moving from the west at 30 knots. Top of the detectable moisture is 35,000 feet MSL. Hail 3/4 inch diameter was reported in the echo at 310/45.

The above report is for the echo area in radarscope picture. The slash mark (/) is used to separate the intensity of the echo from the intensity tendency.

## TIME OF REPORT
Time of observation (24-hour clock) in Greenwich Mean Time. Given only in observations containing hurricane data, an important change in echo pattern, or transmitted out of the RAWARC scan period.

## CHARACTER OF ECHOES

| CHARACTER | DEFINITION | CONTRACTION |
|---|---|---|
| Isolated echo | Isolated solid mass of echo | CELL |
| Widely scattered area | An area less than 1/10 covered with echoes | AREA WDLY ⦶ |
| Scattered area | An area 1/10 to 5/10 covered with echoes | AREA ⦶ |
| Broken area | An area 6/10 to 9/10 covered with echoes | AREA ⦶ |
| Solid area | An area solidly covered with echoes | AREA ⊕ |
| Line of widely scattered echoes | (See widely scattered area) | LN WDLY ⦶ |
| Line of scattered echoes | (See scattered area) | LN ⦶ |
| Line of broken echoes | (See broken area) | LN ⦶ |
| Solid line of echoes | (See solid area) | LN ⊕ |
| Spiral band | Curved line of echoes which occur in connection with a hurricane | SPRL BAND |
| Persisting echo | An echo of moderate or greater intensity which has moved very little or none during past one or more hours | PRSTS 2 HRS |
| Layer aloft | Echo from precipitation layer not reaching ground | LYR ALF |

NOTE:

1. The echo pattern will be classified as a line only if the echoes are arrayed in a recognizable or organized line such as might be reflected from a squall line or front.
2. Spiral bands will be reported mainly with storms of tropical origin.
3. Persisting echoes are indicated in remarks.

## WEATHER SYMBOLS

| | | | |
|---|---|---|---|
| E | SLEET | SW | SNOW SHOWERS |
| L | DRIZZLE | T | THUNDERSTORMS |
| RW | RAIN SHOWERS | S | SNOW |
| R | RAIN | | |

## INTENSITY

| | | | |
|---|---|---|---|
| Very Light | − − | Heavy | + |
| Light | − | | |
| Moderate | No Sign | Very Heavy | + + |

## INTENSITY TENDENCY

| TENDENCY | CONTRACTION |
|---|---|
| Increasing | + |
| Unchanging | NC |
| Decreasing | − |
| Slowly | − |
| Rapidly | + |
| New | NEW |

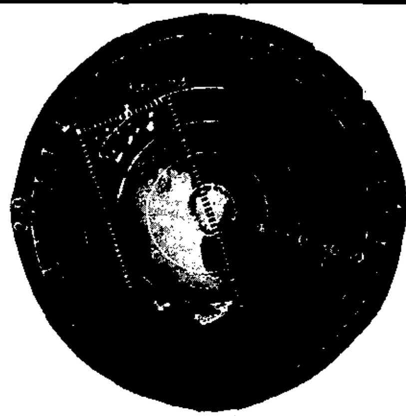
These symbols can be used together. For example: increasing rapidly would be ++, decreasing slowly −−.

## DIMENSIONS OF ECHOES
Width (W) or diameter (D) in nautical miles.

Mean width of lines or spiral bands and mean diameter of cells or roughly circular areas are reported. The average diameter of individual echoes within an area are given as AVG D.

## MOVEMENT
Direction to 16 points of the compass from which, and speed in knots with which, the echo is moving.

RADAR SCOPE



ECHO PATTERN

## LOCATION OF ECHOES
Locations of echoes are relative to the station. The azimuth, in degrees true, and distance, in nautical miles, to salient points of the echo are given.

NOTES:

1. If the echoes are arranged in a straight line, the azimuth and distance to the ends of the line will be given.
2. If the echoes are arranged in a curved line, or in spiral bands, the azimuth and distance will be given to as many points on the longitudinal center of the line or bands as are necessary to establish their shape.
3. If an irregularly shaped area is covered by echoes, the azimuth and range to salient points on the perimeter of the echo will be reported as necessary to outline generally the contour of the clear-cut echo area.
4. If a single echo, such as a thunderstorm cell or an area of echoes of roughly circular shape is observed, the azimuth and range to the center of the cell or area will be reported.

## HEIGHT
Height of top of echo in hundreds of feet above mean sea level.

## UNUSUAL ECHO FORMATION
Certain types of severe storms produce distinctive patterns on the radar scope. For example, the hook-shaped echo associated with tornadoes and the spiral bands with hurricanes. The bright band is a narrow horizontal layer of intensified radar signal a short distance below the 0° C isotherm (Melting level)

## OPERATIONAL STATUS

| STATUS | CONTRACTION |
|---|---|
| (1) Equipment performance normal on PPI scan; echoes not observed | PPINE |
| (2) Equipment out of service for maintenance resulting in loss of PPI presentation. (The contraction is followed by a figure to indicate the number of hours that the equipment is expected to be inoperative.) | PPIOM |
| (3) Equipment inoperative owing to breakdown, resulting in loss of or faulty PPI presentation. | PPINO |
| (4) Normal operation on PPI scan is continuing or resumed | PPIOK |
| (5) Observation omitted for a reason other than those above, or not available. | PPINA |
| (6) Antenna not operating on RHI scan; echo altitude measurements not available. | RHINO |
| (7) A-scope or A/R indicator not operating | ARNO |
| (8) Radar operating below performance standards | ROBEPS |

A contraction pertaining to the operational status of the equipment is sent as required by the table above. In the above list, "PPI" refers to the radarscope (Plan Position Indicator); the additional letters refer to "no echo" (NE), "equipment not operating" (NO), etc.

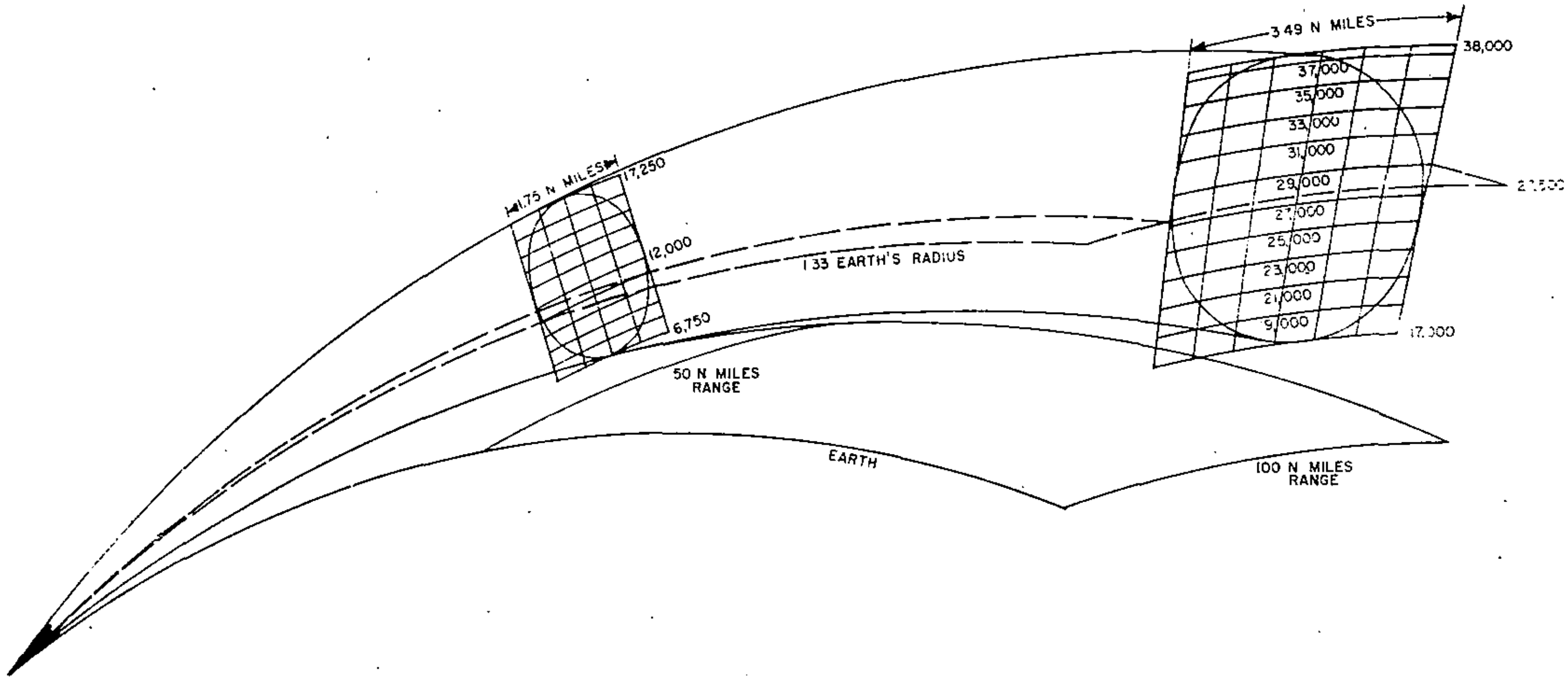
## GENERAL NOTES
Data will be reported and transmitted to the extent that they are available. Additional data may be appended to the report in the form of "remarks" using standard phrase contractions.

* Indicates the report contains an important change in echo patterns.

**U. S. DEPARTMENT OF COMMERCE** **WEATHER BUREAU** **WASHINGTON 25, D. C.**

Figure 1

USCOMM-WB-DC




*The Radar Beam Coverage of a 2° Beam Elevated 2° Above the Horizontal.*

Figure 2

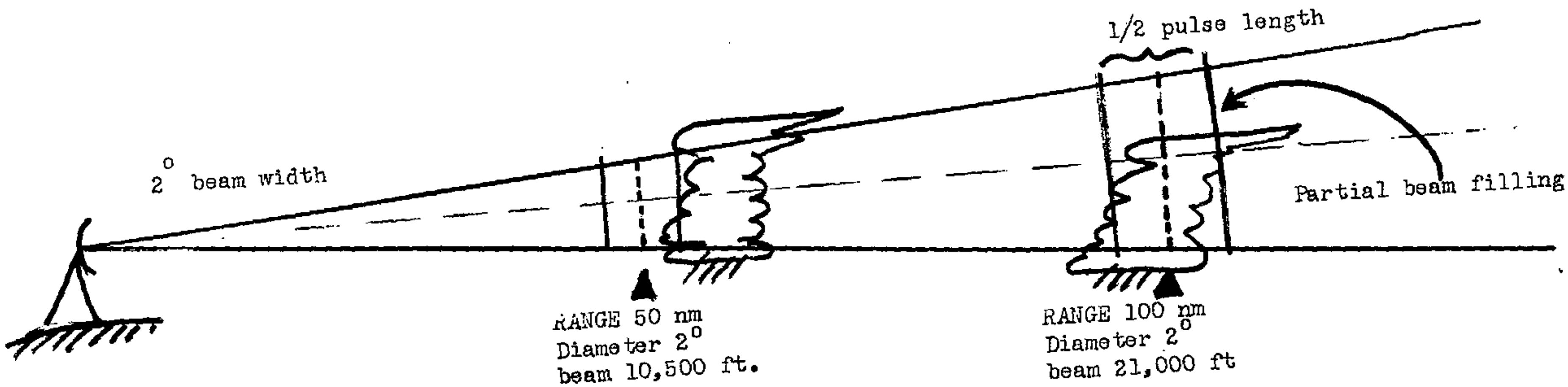
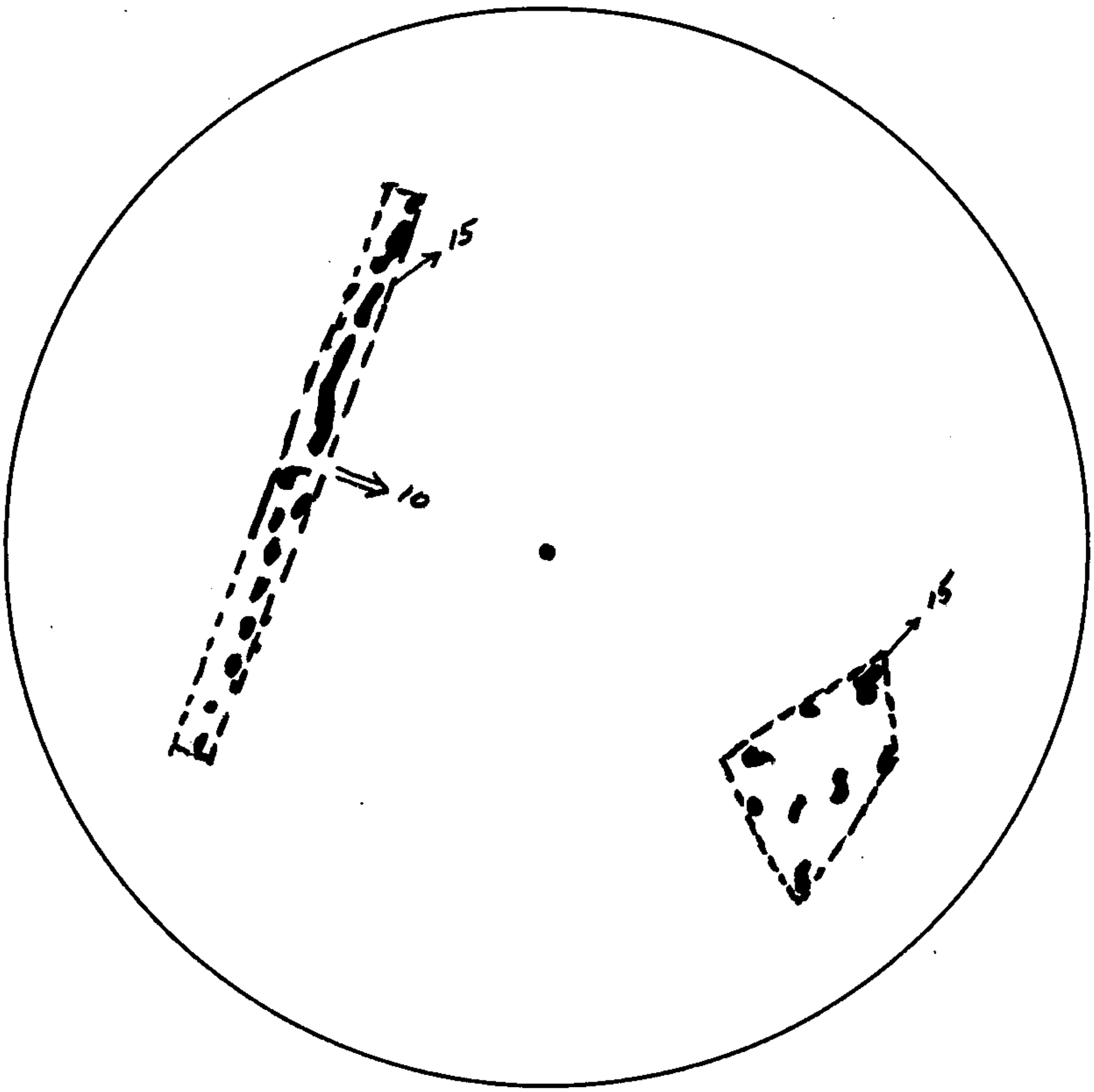



FIGURE 3

Radar Sample Volume




SAC SD 0215 LN RW/ - 350/70 240/85 10W 3010 TOP280 CELLS MOVG 2415

AREA RW-/NC 110/70 130/85 160/90 150/60 AVG D6 STNRY TOP 200

CELLS 2415

FIGURE 4

ARTC RADAR NETWORK

Salt Lake City, Utah

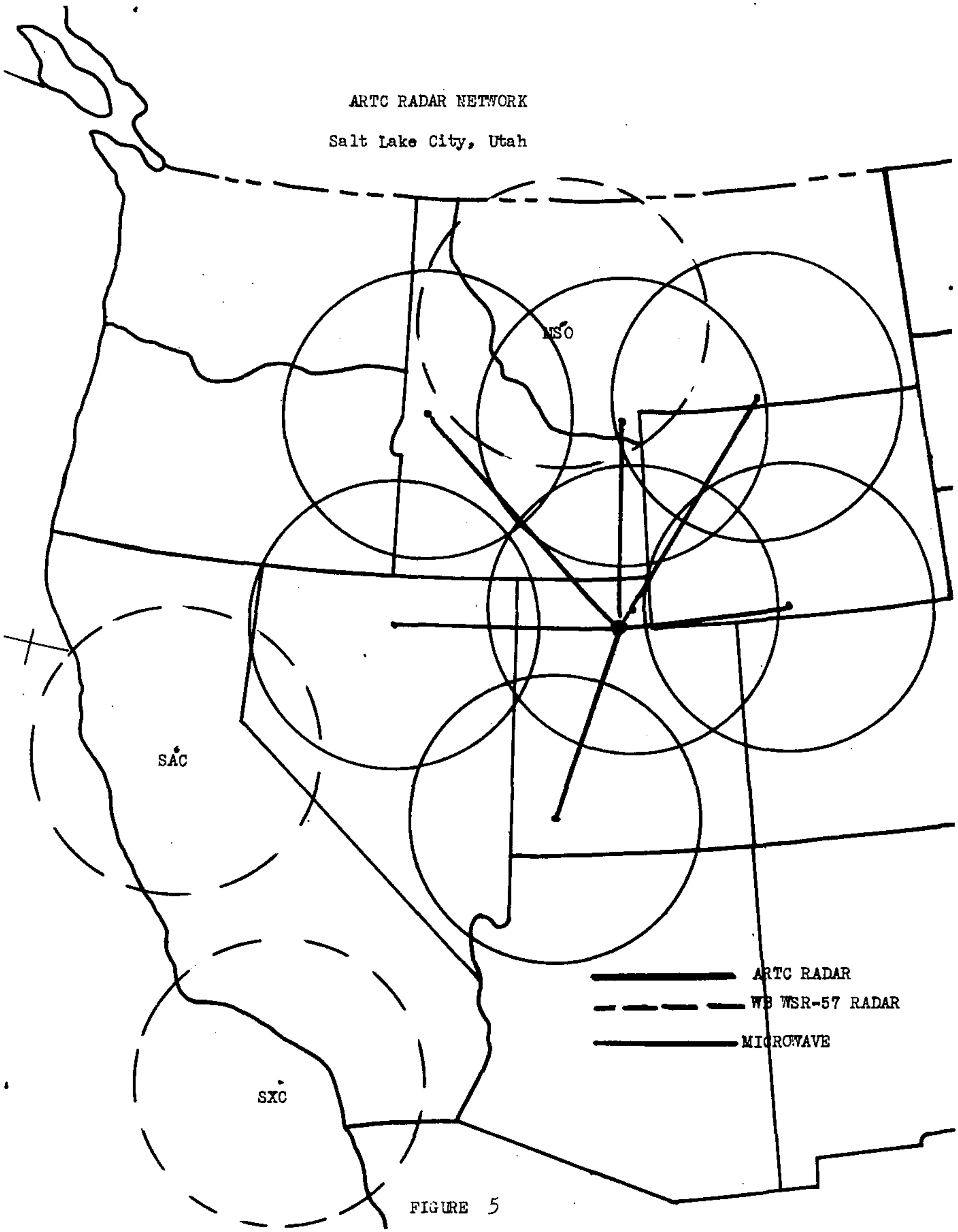
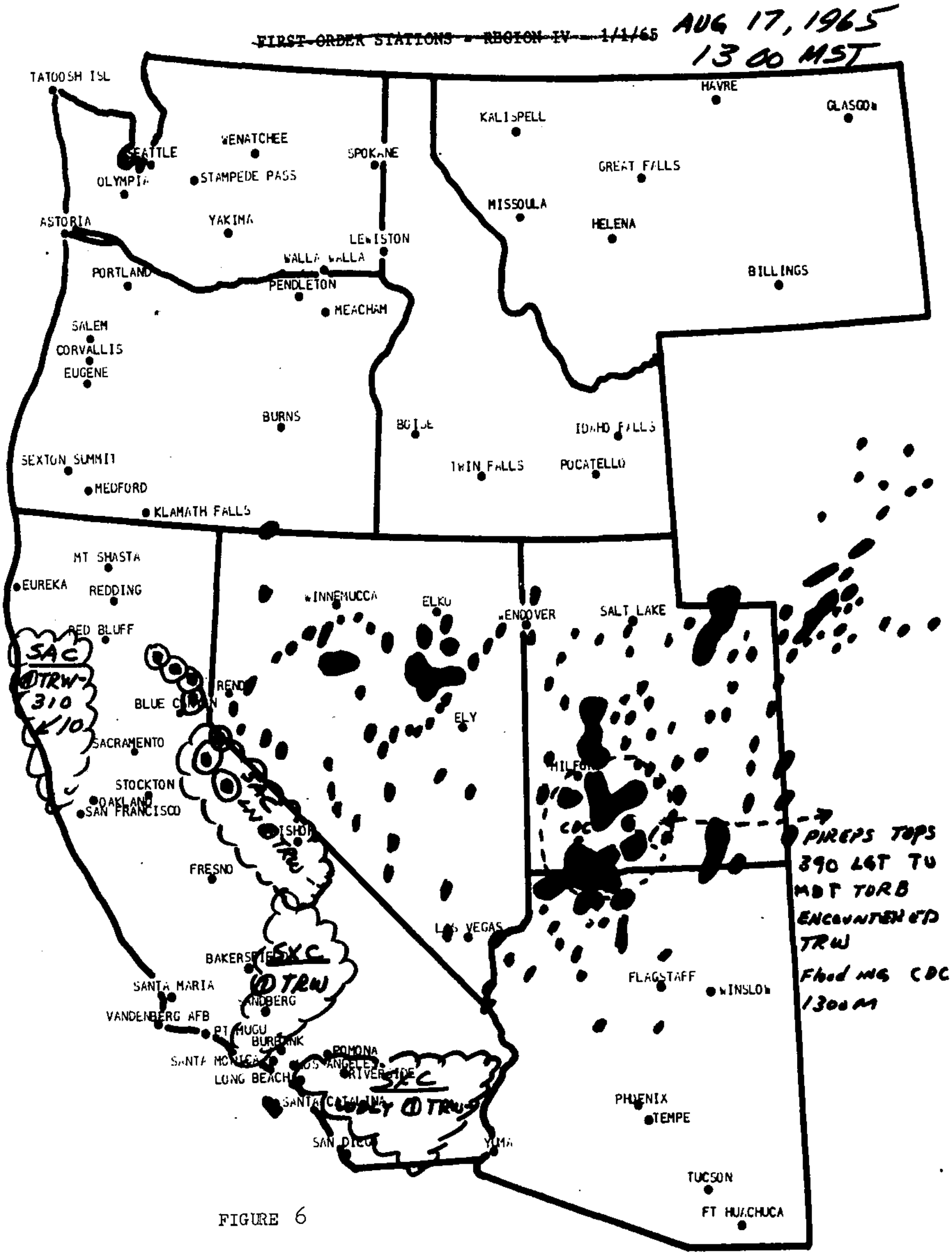



FIGURE 5



~~FIRST-ORDER STATIONS - REGION IV - 1/1/65~~
AUG 17, 1965
1300 MST
TATOOSH ISL
SEATTLE
OLYMPIA
WENATCHEE
STAMPEDE PASS
SPOKANE
YAKIMA
ASTORIA
LEWISTON
WALLA WALLA
PORTLAND
PENDLETON
MEACHAM
SALEM
CORVALLIS
EUGENE
BURNS
SEXTON SUMMIT
MEDFORD
KLAMATH FALLS
KALISPELL
HAVRE
GLASGOW
GREAT FALLS
MISSOULA
HELENA
BILLINGS
BOISE
IDAHO FALLS
TWIN FALLS
POCATELLO
MT SHASTA
EUREKA
REDDING
RED BLUFF
WINNEMUCCA
ELKO
WENDOVER
SALT LAKE
RENO
BLUE CANYON
ELY
SACRAMENTO
STOCKTON
OAKLAND
SAN FRANCISCO
BISHOP
FRESNO
LAS VEGAS
BAKERSFIELD
SANTA MARIA
SANDBERG
VANDENBERG AFB
PT MUGU
BURBANK
SANTA MONICA
POMONA
LOS ANGELES
RIVERSIDE
LONG BEACH
SANTA CATALINA
SAN DIEGO
YUMA
FLAGSTAFF
WINSLOW
PHOENIX
TEMPE
TUCSON
FT HUACHUCA
SAC ① TRW 310 K10
SAC ① TRW
SAC ① TRW
SAC ONLY ① TRW
PIREPS TOPS 390 LGT TO MDT TURB ENCOUNTERED TRW
Flood NG CDC 1300M


FIGURE 6

~~FIRST-ORDER STATIONS - REGION IV - 1/1/65~~

JUNE 3, 1965

SLC SD 1500M AREA SCTD TRWU RWU NO CHG 70 SW DTA 20 SW CDC 50 SW FMC 50 SSE LAS 90 SE TPH 80 WNW ELY 80 W PVU CELLS MOVG W PIREPS TOPS 290-305 MLF TO ELY AREA EXPDG N AND W AREA VERY WIDELY SCTD RWU 100 ESE RKS 30 NNE OGD 30 EW BPI 90 NE RKS MOVMT UNKN

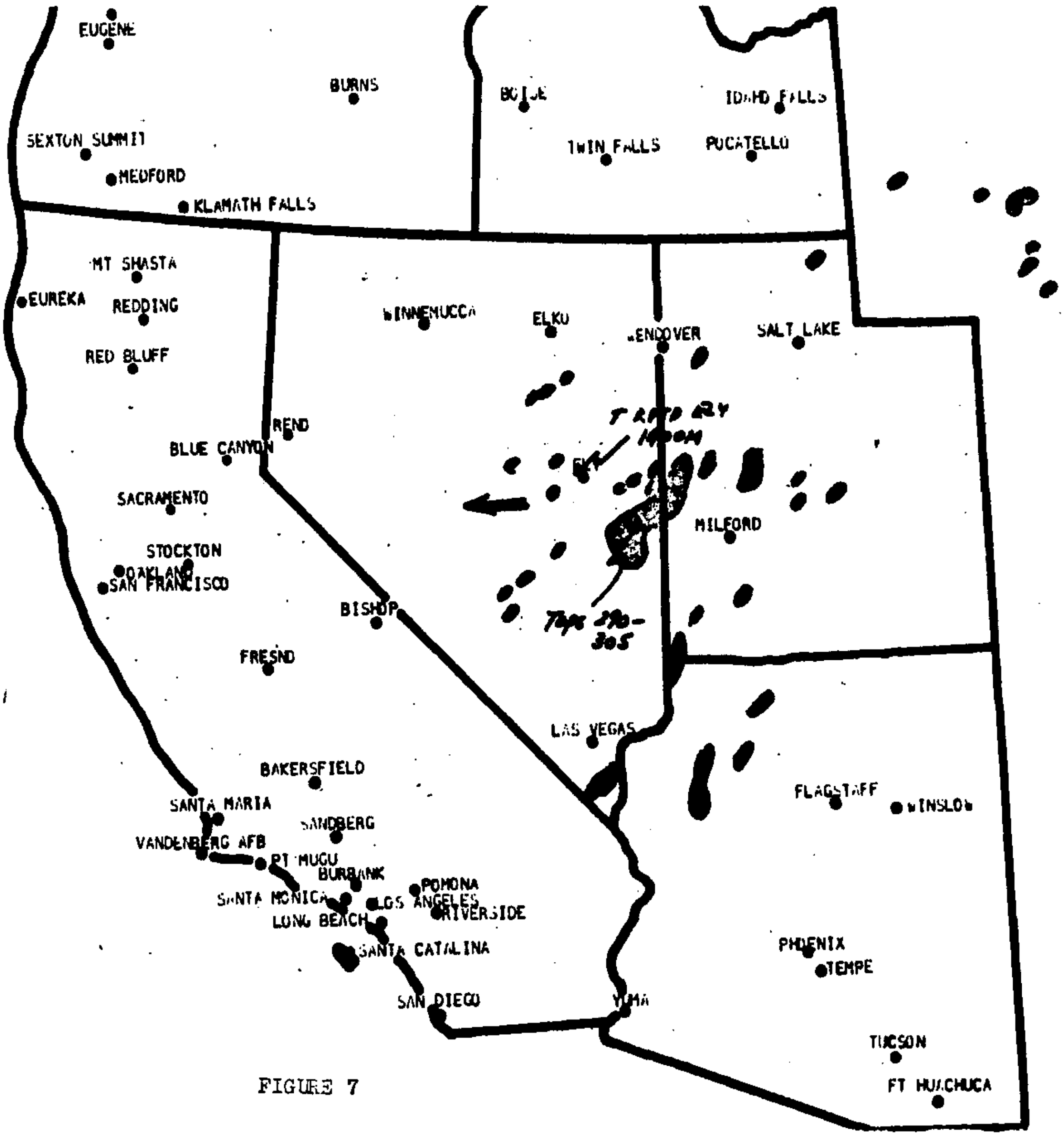



FIGURE 7